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(12) # EUROPEAN PATENT APPLICATION

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(54) Halftoning for hi-fi color inks

(57) A digital printer and a method is provided to print an image having at least two different colors. The printer comprises a first halftone screen associated with a first color and arranged at a first angle, and a second halftone screen associated with a second color and arranged at the first angle. The first and second screens, respectively, comprise dots that do not overlap when the sum of the two colors is less than or equal to 100% coverage.

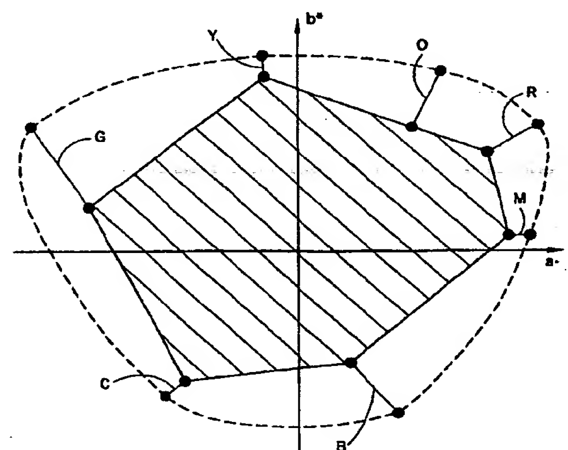

FIG.1

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it is only 15° from the nearest neighbor. In some embodiments, cyan is known to be set at 105°, however, with symmetrical dots this is substantially the same as 15° (and even with asymmetrical dots, it does not make a large difference).

[0010] When four process colors using the above angle combinations are overlaid, the resulting moire or other interference patterns are as small as possible. However, if these angles are off even a slight amount, problems with the image will occur.

[0011] It is known that many color printing systems will include five or more development units having different color colorants. Attempting to incorporate these additional colors is difficult, especially if each color must have a unique halftone angle. Particularly, once there are more than four angles, which must be laid down, the patterning problems discussed above are greatly increased. A known solution to limiting the angles which are incorporated in the printing process is to use the same halftone angle for colors at opposing hue regions such as red or orange used at the same angle as cyan, green used at the same angle as magenta, blue used at the same angle as yellow, and black used at the same angle as gold or silver.

[0012] A limitation placed on the use of the same halftone angles for colors of opposing hues is that the opposed colorants are not to be simultaneously printed. This constraint exists in order to prevent registration errors which degrade the output print.

[0013] It has been considered desirable to determine a manner which would allow for a relaxation of the limitation against a simultaneous printing of opposed colorants. In particular the present invention is directed to an arrangement which relaxes the constraint that the two opposed colorants be mutually exclusive at any given pixel location.

[0014] There are numerous teachings for converting a color signal in one color space to another color space. Such processing are understood to use halftone screens for color printing.

[0015] According to one aspect of the present invention, there is provided a printing apparatus capable of printing multi-color images. The printing apparatus uses halftone screens for each of the colors used in the printing operation. A first halftone screen is provided including a plurality of dots, where the first halftone screen is also arranged at a first angle. A second halftone screen also having a plurality of dots is then formed and also arranged at the first angle, and further is inverse to the first halftone screen. The inverse halftone screen is offset from the first halftone screen whereby the dots of the inverse halftone screen are midway between centers of two dots of the first halftone screen. In accordance with another aspect of the present invention, the printing apparatus allows for a simultaneous printing of colors having opposite hues at substantially the same pixel area.

Figure 1 shows a representative section of color space illustrating a principle of "hi-fi" color according to the present invention;

Figure 2 is a simplified elevational view showing the essential portions of a xerographic engine suitable for image-on-image printing of full-color images;

Figures 3a-3c are a series of illustrations showing halftone screens having the same angle and frequency aligned together for a printing procedure;

Figures 4a-4c illustrate a first halftone screen and a second inverse halftone screen according to the teachings of the present invention and the alignment of such screens for printing operations; and

Figure 5 is a graph showing the printing parameters allowed in accordance with the teachings of the present invention.

[0016] Figure 2 is a simplified elevational view showing the essential portions of a xerographic engine suitable for image-on-image printing of full-color images. Although one embodiment of the invention involves printing an image using image-on-image xerography as will be described, the claimed methods can be applied to any color printing system, including ink-jet, lithography, acoustic ink printing (AIP), etc.

[0017] In the particular architecture of Figure 2 of the present invention, a series of development units successively lay down different primary-colored toners on a single photoreceptor, and the accumulated different-colored toners are then transferred to a print sheet, such as a sheet of paper. As shown in Figure 2, photoreceptor belt 10 is entrained around a series of rollers, and along the circumference of photoreceptor belt 10 are disposed a series of charge corotrons, each indicated as 12, exposure devices indicated as 14, which, as known in the art, could comprise for example an independent laser scanner or LED print bar, and developing apparatus, such as charged donor rolls 16, which apply appropriately-charged toner to the suitably charged or discharged areas created by exposure devices 14. A person of skill in the art of printing will appreciate that each combination of charge corotron 12, exposure device 14, and development unit 16 along the circumference of photoreceptor 10 represents an "imaging station" capable of placing toner of a particular primary or other color in imagewise fashion on photoreceptor 10. The location of where these colors are to be placed will, of course, be determined by the various areas discharged by the series of exposure devices 14. There may also be, disposed along photoreceptor belt 10, any number of ancillary devices, such as cleaning corotrons, cleaning blades, etc., as would be known to one of skill in the art. By causing a particular image area on the photoreceptor belt 10 to be processed by a number of stations, each station corresponding to one primary color, it is apparent tat a full-color image, comprising imagewise-placed toners of the different primary colors, will eventually be built-up on

same time. Particularly, the merging of these colors provides an improved neutral tone and gray color processing.

[0026] A related issue is the trade-off between colorant area coverage limitations and smoothness of sweeps from neutral to off-neutral regions. Often in printing, such as for ink jet printing, mainly K is used to render dark neutrals, in order to constrain the maximum area coverage near black. However, this can lead to an unstable and non-smooth response as one moves from neutral locations at the point where the colored ink starts printing. The use of opposed colorants around the neutral axis enables a smooth transition. In addition, opposed colorants use less total ink area coverage than would be required if conventional four-colorant (CMYK) or other "hi-fi" systems were used.

[0027] Thus, mixing opposing colorants allows for the movement across the neutral axis in a smooth transition. This concept can be explained in an example of a color sweep from cyan through red. Moving across this color spectrum there will be some neutral or gray level. Therefore when the image sweeps from orange to cyan, if black is used for the neutral or gray level, there will be a transition from red to all black to cyan. What will happen is that the various colorants will need to be turned on and off which can result in a clear step distinction in the color sweep. However, since the present invention can use a combination of colors (such as opposed colors cyan and red as well as orange) to create the neutral grays, there is no movement down to a zero colorant disbursement of the cyan and/or red. Rather the transition moves in a more balanced manner of increasing and decreasing levels of these colorants to create greater uniformity in this transition.

[0028] In general, a halftone configuration that allows the coexistence of opposed colorants affords greater flexibility in the design of hi-fi separation algorithms. It is to be appreciated that while dot-off-dot type printing does not have registration tolerances as tight as dot-on-dot printing, misregistration and dot-growth problems are factors to take into consideration when developing a dot-off-dot printing system using the inverse halftone screen of the present invention. Therefore, the following discussion is provided to describe an example of how the combined area coverage of two opposed colorants (in this example, cyan and orange) can be limited to minimize registration artifacts.

[0029] It is first considered that the contone (e.g. 8-bit) inputs are C (for cyan), and O (for orange), for their respective halftone screens. A constraint of the present invention is to minimize or eliminate the possibility of overlap between these two colorants. Using the present inverted halftone screen design, this means it is required that:

$$O+C<=255, \qquad (1)$$

with equality only when O=255 or C=255. Therefore, the following constraint is imposed:

$$O<=f(C)<=255-C, \qquad (2)$$

where f(C) serves as an upper boundary for the amount of orange allowed to coexist with the cyan.

An example of f(C) is:

$$f(C)=255^*(1-C/255)^2 \qquad (3)$$

A graph representing the foregoing concepts is provided in Figure 5. Outer boundary line 50 shows the 255-C restriction. Lower boundary curve f(C) 52 shows a more refined restriction parameter which can be used to eliminate misregistration concerns and spot overlap which might occur due to spot growth.

[0030] In creating the hi-fi separations, the two opposed colorants are then designed to satisfy constraint (2). Note that the conventional condition of O and C being mutually exclusive reduces to the special case where f(0) = 255; and f(C) = 0 when C>0. The proposed configuration thus allows for a smoother transition from regions of color space that require cyan to those that require orange.

[0031] It is to be appreciated that while the foregoing examples have involved the use of cyan and orange, the present concepts are equally applicable to other color combinations, non-gamut colors such as silver or gold with black, fluorescent colors and their nearest equivalent or opposed color (e.g. fluorescent red with cyan), or varying intensity of the same color (e.g. dark cyan or light cyan, as will images other than 8-bit images).

[0032] Additionally, whereas Figure 5 shows a specific constraint in accordance with the function f(C), other functions may be available which are equally applicable, and a key point to the constraints designed above is to prevent the overlapping of dots due to the misregistration or oversizing of dots during the printing process.

[0033] The preceding description has discussed the present invention in connection with a hi-fi printing system which uses more than four colorants (i.e. CMYK plus at least one additional color such as red, green, blue, silver, gold, etc.). However, the present invention may be implemented in a printing system which uses less than four colors as well as a system that does not use a black (K) colorant. Rather, instead of the black colorant, an opposing color of primary colors (e.g. CMY) may be used (e.g. one of red, orange, green, blue or other appropriate color) which would still allow generation of the various hues required for printing including a black color obtained by the combination of colorants used within the system. Under such a configuration, a print imaging system not using black may be implemented which still uses the four-level coloring configuration.

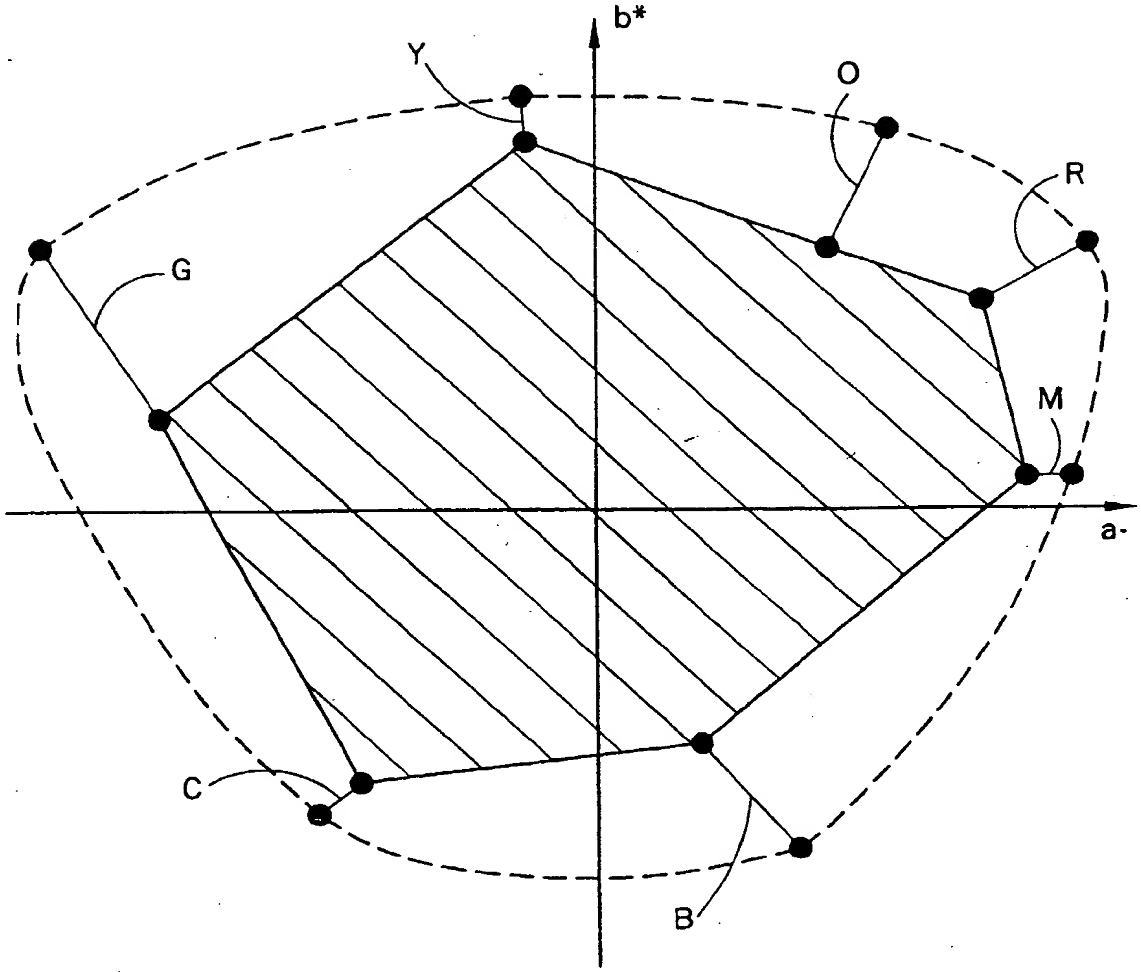

FIG.1

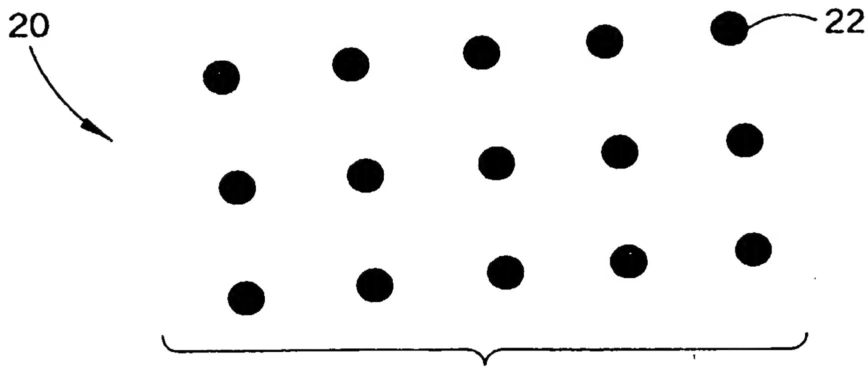

FIG.3a

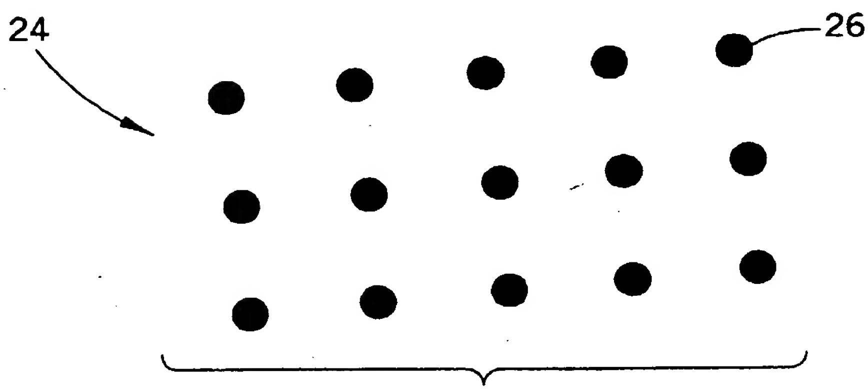

FIG.3b

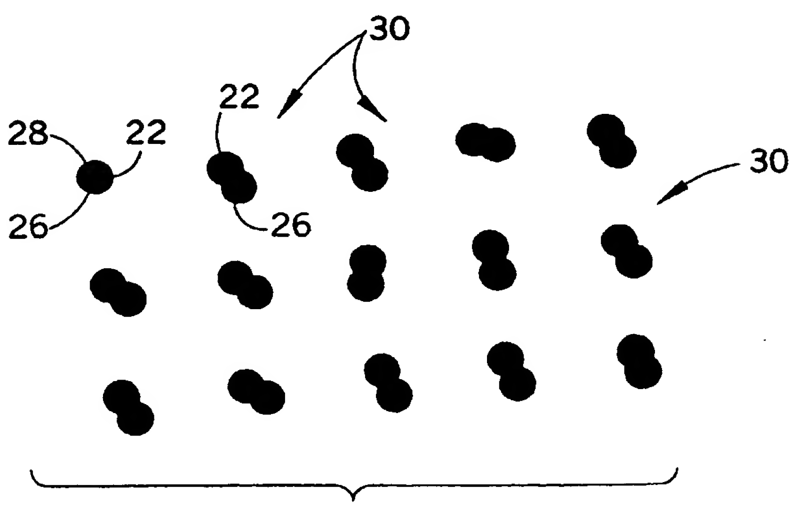

FIG.3c

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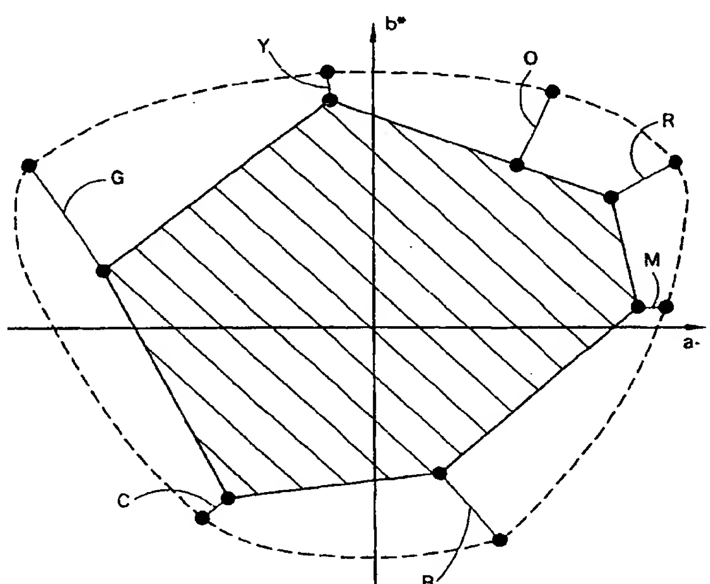

FIG.1

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